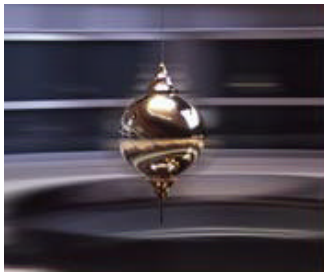

Uncovering an Indiana Treasure . . .

The Foucault Pendulum

When the Indiana State Museum was located in the old City Hall building at 202 North Alabama St., Indianapolis, the main focal point upon entering the rotunda was a large swinging bronze ball. School children would flock to the railing where they were quickly mesmerized by the hypnotic sway of the bob. These same children would then let out a loud "Hurray!" when the ball would knock down one of the small red pegs that encircled the swinging orb. For many years, the Foucault Pendulum was the signature exhibit at the Indiana State Museum at the Alabama Street address. As these school children became adults, and they heard that the museum would be moving to a new facility in White River State Park, that one of the most asked questions was, "Is the pendulum moving too?"

So what is a "Foucault Pendulum?" The most common misconception is that it is some sort of clock. Actually, the pendulum is an experiment that was originally created by a French astronomer and physicist, Jean Bernard Leon Foucault (pronounced Foo-Koe) (1819-1868), inventor of the gyroscope. Unlike other scientists who demonstrated that the earth rotates by looking at the movement of the sun, moon or stars, Foucault was the first person to illustrate the earth's rotation by using an object fixed on the earth itself. And how did he do that?

First of all, you need to understand how a pendulum works and a little about Newton's First Law of Motion. A pendulum is an object that hangs from a fixed point, and when pulled back and released, it swings down, out and up. Newton's First Law of Motion states that "an object at rest tends to remain at rest and an object in motion tends to continue in motion in the same straight line, at the same speed, unless acted upon by an outside force." The pendulum bob is the body in motion. Its inertia (an object's resistance to changes in motion) makes it swing straight out, and the force of gravity pulls it back and down. It will continue its swing in a straight line and at the same speed until air resistance (the outside force) eventually slows it down. Think of it like sitting in a swing. When you first sit in a swing seat you are basically still. However, when you push off with your feet you put yourself in motion. You will stay in motion due to inertia, which causes you to swing out and up, and gravity will pull you down. If you do nothing at all, you will continue to swing (staying in motion) at the same speed – until air resistance would eventually slow you down, or you drag your feet and stop yourself (thus the outside force). You will also swing in a straight line, back and forth, rather than side to side or in circles.

The pendulum works the same way. The museum's pendulum is attached to a fixed point high in the ceiling. The "bob," which is the large bronze ball at the wire's end, swings back and forth in a straight line. Since air resistance would eventually stop the pendulum from swinging after a few hours, an iron collar is attached to the top of the wire where the pendulum hangs. Think of this iron collar as a large metal ring that is clamped to the top of the wire. It moves back and forth as the wire moves. In the ceiling surrounding the top of the collared wire is a doughnut-shaped electromagnet. This magnet is what keeps the pendulum moving back and forth. As the bob swings out, the iron collar touches the magnet; the magnet "grabs" the collar and then shuts off, allowing the wire to swing back. In a way, this is like leaning back and forth to keep you moving while sitting in a swing. If you quit leaning, you would slow down and soon come to a complete stop. However, as long as you keep shifting your weight you will keep swinging. Likewise, the iron collar and the magnet keep the pendulum going without altering the path of the pendulum's swing.

So how does the pendulum demonstrate the earth's rotation? Until a few hundred years ago, many people believed that the earth was flat, and it supposedly remained still in space while the sun, moon and stars rotated around it. This is because we naturally assume that the base on which we stand is stable unless our eyes or sense of balance tells us otherwise. Foucault's experiment succeeded in demonstrating the earth's rotation by showing that a pendulum, which is supposed to swing in a straight line, appears to swing in a different direction after the passage of a few hours.

In 1851, after two earlier pendulum experiments, Foucault suspended a ball of 61 pounds on a steel wire 220 feet long

from the dome of the Pantheon in Paris. Protruding from the ball was a pin adjusted to draw a mark through a layer of wet sand beneath the ball. Foucault pulled the ball to the side and released it. With each swing it made a mark in the sand and appeared to rotate in a clockwise direction, thus demonstrating his prediction that the pendulum would revolve about 270 degrees in 24 hours and show the rotation of the earth. Since we know that with inertia and gravity the pendulum should swing in a straight line, it must be the floor beneath the pendulum that moves. Since the floor is attached to the earth, the earth must then rotate.

The pendulum in the Indiana State Museum turns 240 degrees in 24 hours. It takes 40 hours for the pendulum to knock down the complete 360-degree circle of 144 black pegs. One peg is knocked down about every eight minutes. This is due to the latitude of Indianapolis (39° - 45') and the length of wire, which is 59 feet 3 inches. The longer the wire, the slower the bob swings, and the less it is hindered by friction with the air. At the North Pole, the rotation of the pendulum would be a full 360 degrees in 24 hours and a pendulum at the equator would not rotate at all. The further we go from the North Pole toward the equator, the wider the earth becomes; thus, it requires a longer period of time for the earth to revolve under the pendulum. Below the equator the rotation begins again, but in a counter-clockwise direction.

As a result of the earth's rotation, we experience a wider distribution of rain over the earth. Without the rotation, cool air would flow steadily from pole to equator. Warming and rising as it moved, the air would drop its water content almost constantly near the equator and deserts would form in the northern and southern parts of the earth. The rotation helps change this pattern by introducing an east or west deflection. During plane flights, navigators must allow for deviation to the right when flying in the northern hemisphere and to the left in the southern hemisphere. During space flights, the earth's rotation creates special problems, especially in navigating to and from the moon. If you dropped a golf ball from the Empire State building with no wind, the rotation would cause the ball to land nearly five inches to the east of true vertical – proof that the earth really does rotate!

There are more than 30 Foucault Pendulums in the United States. At the Indiana State Museum, the 212-pound bob is made of hollow bronze and filled with 200 pounds of lead shot. Its total weight is 412 pounds. It is suspended with one-eighth inch standard aircraft control cable. This cable was developed to operate parts of the wing and tail of an airplane and is designed not to stretch. If rope were used to hold the bob, it would eventually touch the floor. The pendulum makes a swing of about 8.5 feet in 10 seconds. It is very important that no one touches the bob as it swings because this alters the speed and accuracy, thereby destroying the results of the experiment. Even so, vibrations from the building and from trucks on the street sometimes make the pendulum swing in a narrow elliptical path only one or two inches wide.

The museum's pendulum was made by the California Academy of Sciences in San Francisco. That manufacturer also made the Smithsonian Institution pendulums and the United Nations pendulum in New York City. Originally installed in the old museum building in December 1967, the Indiana State Museum's Foucault pendulum currently resides in the Andrew J. and Jane M. Paine Tower.

Additional Resources:

Benyon, Zinaida. *About Foucault Pendulums and How They Prove the Earth Rotates*. California Academy of Sciences, 2003. www.calacademy.org/products/pendulum

Foucault Pendulum. Smithsonian Institution, 2003. www.si.edu/resource/faq/nmah/pendulum.htm

Tobin, William. *The Man W ho Proved the Earth Rotates: The Life and Science of Léon Foucault: Photographer, Physicist, Journalist, and Astronomer*. New York: Cambridge University Press, 2003.